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Municipal Waste Combustion Assessment: Waste Co-Firing

Energy and Environmental Research Corp., Durham, NC

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MUNICIPAL WASTE COMBUSTION ASSESSMENT: WASTE CO-FIRING

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ABSTRACT

This report provides an overview of waste co-firing and auxiliary fuel fired technology and identifies the extent to which co-firing and auxiliary fuel firing are practiced. Waste co-firing is defined as the combustion of wastes such as sewage sludge, medical waste, wood waste, agricultural waste, etc., in a unit that is designed to burn municipal solid waste (MSW) or refuse-derived-fuel (RDF) as a major fraction of total fuel input. Auxiliary fuel firing is defined as the practice whereby coal, fuel oil or natural gas is fired in a municipal waste combustor under conditions when waste feed quantities are interrupted. This is a fairly common practice for dedicated RDF boilers, and there may be additional mass burn MWCs that meet the definition of auxiliary fuel firing. This report includes descriptions of technologies used by facilities that meet these definitions, characterizes the population, and discusses design and operating practices and available emissions data from each facility. The report concludes with a discussion of recommended good combustion practices for waste co-firing combustors and auxiliary fuel fired MWCs.

FOREWORD

Based upon its analysis of Municipal Waste Combustors (MWC), the Environmental Protection Agency (EPA) has determined that MWC emissions may reasonably be anticipated to contribute to the endangerment of public health and welfare and warrant further regulation. As a result, EPA's Office of Air Quality Planning and Standards is developing emission standards for new MWCs under Section 111(b) of the Clean Air Act (CAA) and guidelines for existing MWCs under Section 111(d) of the CAA.

In support of these regulatory development efforts, the Air and Energy Engineering Research Laboratory in EPA's Office of Research and Development has conducted an in-depth assessment of combustion control practices to minimize air emissions from MWCs. The results of this assessment are documented in the following reports:

Municipal Waste Combustion Assessment: Combustion Control at New Facilities, August 1989 (EPA-600/8-89-057)

Municipal Waste Combustion Assessment: Combustion Control at Existing Facilities, August 1989 (EPA-600/8-89-058)

Municipal Waste Combustion Assessment: Fossil Fuel Co-Firing, July 1989 (EPA-600/8-89-059)

Municipal Waste Combustion Assessment: Waste Co-Firing, July 1989 (EPA-600/8-89-060)

Municipal Waste Combustion Assessment: Fluidized Bed Combustion, July 1989 (EPA-600/8-89-061)

Municipal Waste Combustion Assessment: Medical Waste Combustion Practices at Municipal Waste Combustion Facilities, July 1989 (EPA-600/8-89-062)

Municipal Waste Combustion Assessment: Technical Basis for Good Combustion Practice, August 1989 (EPA-600/8-89-063)

Municipal Waste Combustion: Multi-pollutant Study, Emission Test Report, Maine Energy Recovery Company, Refuse-Derived Fuel Facility, Biddeford, Maine, Volume I, Summary of Results, July 1989 (EPA-600/8-89-064a)

Municipal Waste Combustion: Multi-Pollutant Study, Emission Test Report, Mass Burn Refractory Incinerator, Montgomery County South Ohio, Volume I, Summary of Results, August 1989 (EPA-600/8-89-065a)

The specific objectives of this report, "Municipal Waste Combustion Assessment: Waste Co-Firing," were to provide an overview of waste co-firing technology and identify the extent to which waste co-firing is practiced in combustion systems designed to burn municipal solid waste and refuse-derived-fuel.

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1.0 INTRODUCTION

This report provides an overview of waste co-firing technology and identifies the extent to which waste co-firing is practiced in combustion systems designed to burn municipal solid waste (MSW) and refuse-derived-fuel (RDF). Section 2.0 defines waste co-firing and auxiliary fuel firing and includes descriptions of technology used by facilities that meet these definitions. Section 3.0 characterizes the population of waste co-firing and auxiliary fuel firing municipal waste combustors (MWCs) and discusses design and operating practices and available emissions data from each facility. Section 4.0 concludes the report with a discussion of recommended good combustion practices for waste co-firing and auxiliary fuel fired MWCs.

2.0 WASTE CO-FIRING

2.1 Definitions

Waste co-firing is defined as the combustion of wastes such as sewage sludge, medical waste, wood waste, agricultural waste, etc., in a unit that is designed to burn MSW or RDF as a major fraction of total fuel input. All MWC designs have the potential to be waste co-firing units; however, some facility operating permits specify the extent to which waste co-firing can be practiced. Auxiliary fuel firing is defined as the practice whereby coal, fuel oil or natural gas is fired in a municipal waste combustor under conditions when waste feed quantities are interrupted. This is a fairly common practice for dedicated RDF boilers, and there may be additional mass burn MWCs that meet the definition of auxiliary fuel firing.

Fossil fuel co-firing is distinct from waste co-firing and from auxiliary fuel firing. Fossil fuel co-firing is defined as the combustion of RDF with another fuel (usually coal) in a unit originally designed to fire the other fuel. Fossil fuel co-firing is generally confined to commercial and utility boilers. Fossil fuel co-firing practices are discussed fully in a separate report and will not be included in this report.[1]

2.2 Description of Technology

There are two broad classes of municipal waste combustors that can be distinguished by fuel firing characteristics. These are mass burn combustors and RDF-fired combustors. Mass burn units burn largely unprocessed waste; usually only large, bulky, non-combustible material is removed prior to charging. RDF-fired systems burn a more finely-processed waste which has a lower inert (ash) fraction by weight and a higher heating value than raw MSW.

2.2.1 RDF Processing

The main steps in MSW processing for the preparation of RDF are coarse shredding; magnetic separation; screening to remove glass, grit, and dirt; fine shredding; and air classification to remove the heavy fraction. These processing steps are illustrated in Figure 2-1.[2] The degree and order in which these steps are utilized are highly site-specific, resulting in variable RDF characteristics from different RDF processing plants. Depending on the

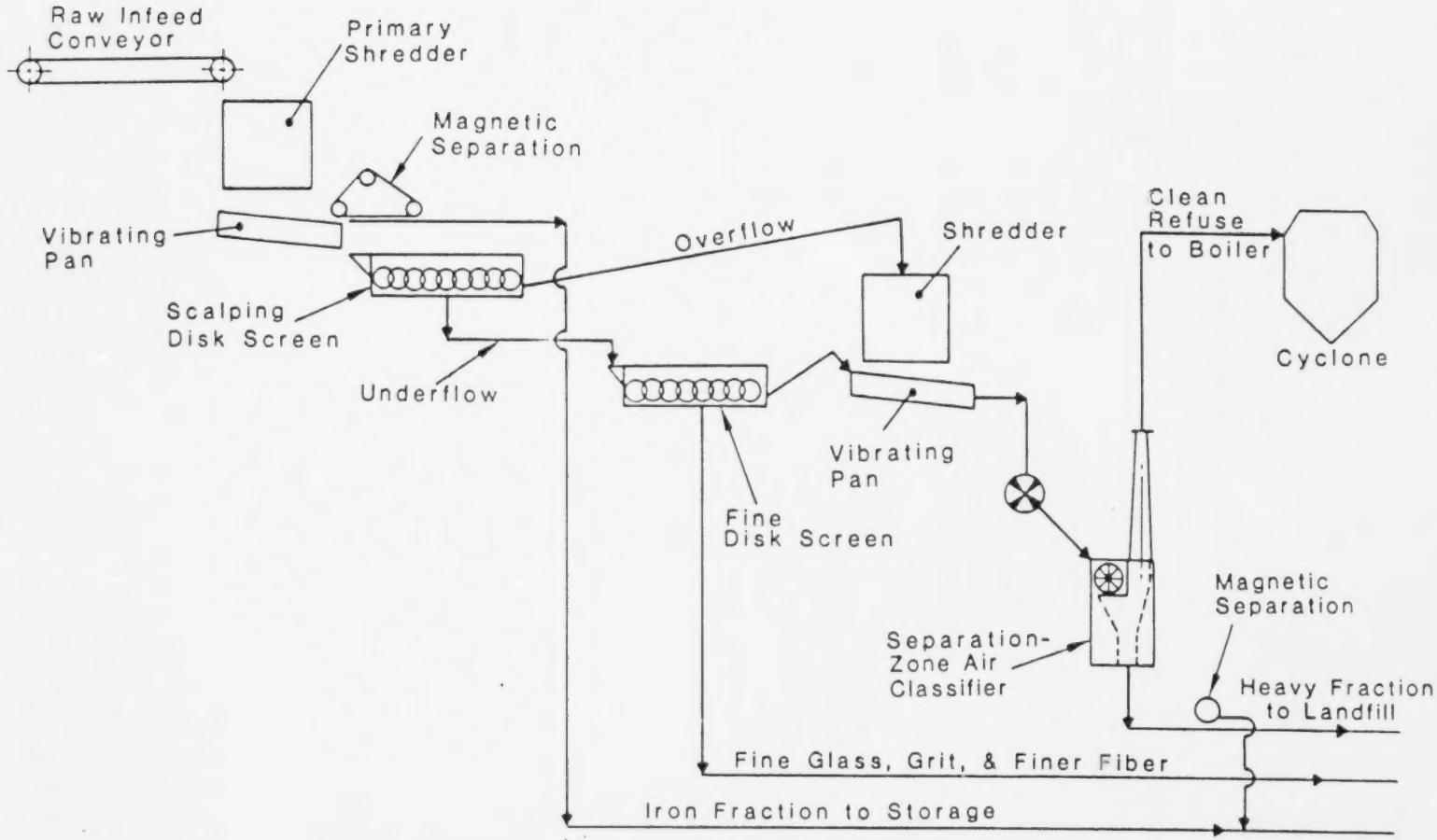

Figure 2-1. Schematic of Typical RDF Processing

degree of processing, RDF can range from coarse-shredded material to a powdered form. The various types of RDF have been classified by the American Society for Testing and Materials (ASTM) and are listed in Table 2-1.[2] A typical moisture content for coarse RDF (c-RDF) and fluff RDF (f-RDF) is 25 percent, whereas powdered RDF (p-RDF) typically contains less than 5 percent moisture. Correspondingly, typical heating values for coarse and fluff RDF are 4500-6000 Btu/lb (1.05×10^7 - 1.40×10^7 J/kg), whereas powdered RDF approaches 7500 Btu/lb (1.74×10^7 J/kg).

2.2.2 RDF Combustion

RDF combustion technology includes suspension firing, semi-suspension firing, and fluidized bed combustion units. Suspension firing is restricted largely to RDF co-fired units as defined in Section 2.1, and these units are discussed fully in a separate report.[1]

2.2.2.1 RDF Spreader Stokers. Nearly all dedicated RDF combustors are spreader stokers, which burn RDF in a semi-suspension mode. The most common type of waste fuel burned in a spreader stoker boiler is fluff RDF. The fuel is normally injected into the combustor through airswept distributors located on the front wall of the furnace. A portion of the fuel burns in suspension and the remainder falls to a traveling grate where burnout is completed. The traveling grate moves slowly from the rear to the front of the furnace and discharges the ash bed into a water-filled quench pit. The majority of RDF spreader stokers use preheated combustion air which is injected through one or more plenums beneath the traveling grate as primary (underfire) air and through rows of nozzles on the walls of the boiler as secondary (overfire) air. Figure 2-2 shows a profile of a typical RDF spreader stoker boiler.[2] The normal control scheme in an RDF spreader stoker involves modulation of feed rates in response to steam flow or pressure. Combustion air distribution and flow rate may also be automatically controlled in response to a continuous oxygen reading at the boiler exit. All RDF spreader stokers use waterwall boilers to produce steam and, in some cases, generate electricity, and the majority of units using this design are equipped with oil or natural gas burners that can provide up to 100 percent of design heat input.

2.2.2.2 Fluidized Bed Combustors. A Fluidized Bed Combustor (FBC) comprises a reaction vessel equipped with a gas distribution or orifice plate at the bottom. A bed of solid particles above the gas distribution plate is

TABLE 2-1. ASTM CLASSIFICATION OF REFUSE DERIVED FUELS

TYPE OF RDF	DESCRIPTION
RDF-1 (MSW)	Municipal solid waste used as a fuel in as-discarded form, without oversize bulky waste (OBW).
RDF-2 (c-RDF)	MSW processed to coarse particle size, with or without ferrous metal separation, such that 95 weight percent passes through a 6 inch square mesh screen.
RDF-3 (f-RDF)	Shredded fuel derived from MSW and processed for the removal of metal, glass, and other entrained organics. The particle size of this material is such that 95 weight percent passes through a 2 inch (5.1 cm) square mesh screen. Also called "fluff RDF."
RDF-4 (p-RDF)	Combustible waste fraction processed into powdered form, 95 weight percent passing through a 10-mesh (0.035 inch or 0.89 cm square) screen.
RDF-5 (d-RDF)	Combustible waste fraction densified (compressed) into the form of pellets, slugs, cubettes, briquettes, or some similar form.
RDF-6	Combustible waste fraction processed into a liquid fuel (no standards developed).
RDF-7	Combustible waste fraction processed into a gaseous fuel (no standards developed).

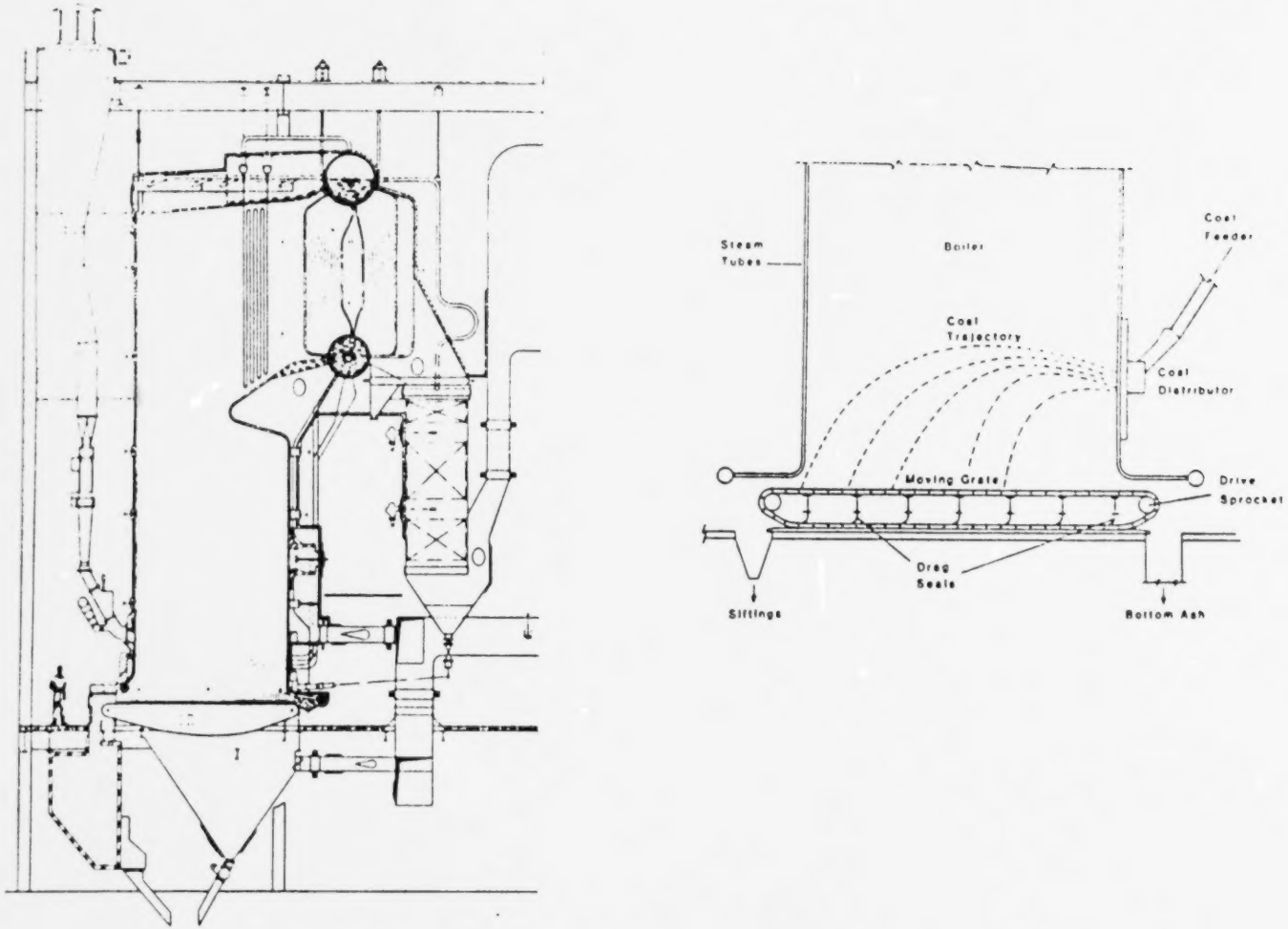

Figure 2-2. Profile of a Typical Coal Fired Spreader Stoker Boiler

fluidized by the upward flow of gas (air) introduced through a windbox or plenum below the plate. Some means of returning entrained material to the bed --either a disengaging space above the bed or a mechanical dust collector (e.g. a cyclone)--must also be provided. A common means of disengaging solids from the gas is to design the reactor with an increased cross-section in the area above the bed (the freeboard). The increased area results in lower air velocity, causing the solid material to disengage from the gas stream and fall back to the bed. Finally, mechanisms for mass transfer to and from the bed are required (fuel and other solids must be supplied to the bed while ash and other byproducts must be removed from it on a continuous basis). Figure 2-3 provides a schematic representation and illustrates the general elements of a FBC.[3]

Combustion in the FBC occurs primarily within the bed, which consists of an inert material (typically sand, limestone, or alumina) interspersed with fluidizing air and particles of fuel and ash. Fluidization occurs as the pressure drop of the air traversing the bed equals the weight per unit of bed cross-sectional area. The air velocity at the point where fluidization begins is termed the minimum fluidization velocity. Increasing the velocity from this point causes the bed to expand to allow the air to bubble through it. At approximately three to five times the minimum fluidization velocity, the bed resembles a violently boiling liquid. It is in this region that conventional fluidized bed combustors (also called fixed bed or bubbling bed) operate.

Increasing the air velocity beyond levels utilized in bubbling bed FBCs leads to increased entrainment of bed material, until a significant portion of the bed is being carried from the main reactor vessel. The circulating fluid bed (CFB) combustor operates in this region, with air velocities approximately twenty times the minimum fluidization velocity. In the CFB the solids are disengaged from the gas stream in a cyclone and are reinjected into the reactor, as shown in Figure 2-4.[4] The bed is not well defined in the CFB; rather, the reactor vessel and cyclone comprise a solids recirculation loop.

FBCs are characterized by extremely efficient mass and heat transfer, i.e. very uniform temperatures and mass compositions are observed both in the bed and in the freeboard. Efficient mass and heat transfer allows both conventional and waste fueled FBCs to operate at lower excess air and temperature levels than many other systems. Waste fired FBCs typically operate at excess air levels between 30 and 100 percent (5 to 10 percent O_2 in

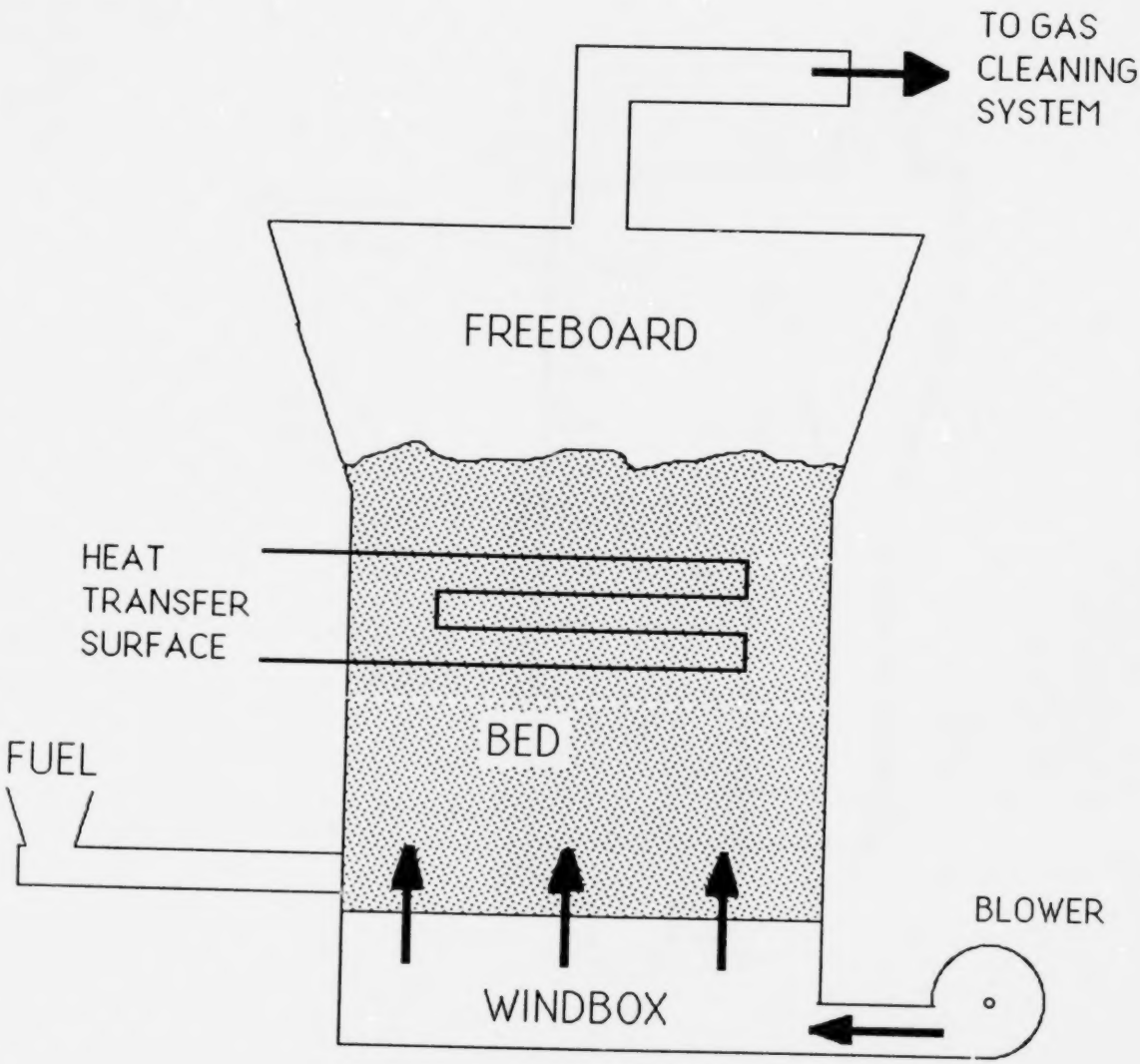

Figure 2-3. Elements of a Fluidized Bed Combustor

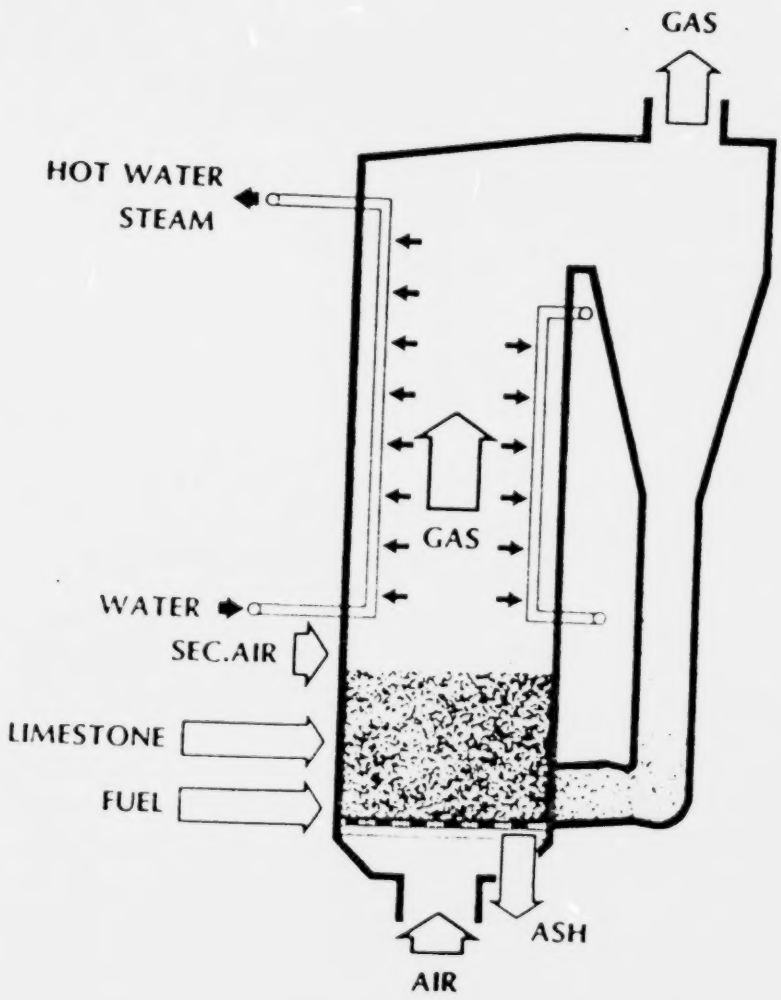

Figure 2-4. Circulating Fluidized Bed Combustor

the dry flue gas) and at bed temperatures around 1500°F (815°C). Low temperatures are a necessity for waste firing units since higher temperatures lead to softening of glass in the fuel which results in bed agglomeration. In bubbling bed units, heat transfer surfaces are sometimes incorporated in the bed to maintain the low temperature. CFB units maintain temperature by controlling the solids density in the solids recirculation loop; in-bed heat removal is not typical for CFBs.

2.2.3 Mass Burn Combustors

There are numerous types of mass burn MWCs in the existing population of facilities, including large field-erected units with individual capacities ranging from 100 to 1000 tpd (91-907 tonnes/day), and modular shop-fabricated units that range in size from 5 to 120 tpd (4.5 to 109 tonnes/day). The large mass burn systems include conventional mass burn waterwall combustors, rotary waterwall combustors, and refractory wall incinerators. All of the large mass burn units operate in an excess air mode, with typical excess air levels ranging from 30 to 150 percent.

There are also a wide variety of modular mass burn combustion designs available. Most units include multiple combustion chambers, with the waste burning in the primary chamber and burnout of combustible products being completed in a secondary chamber. A main design distinction in this subcategory of combustors is the distribution of combustion air. Some units operate with less than stoichiometric air requirements supplied in the primary chamber. The primary chamber essentially operates as a gasifier, producing a fuel-rich effluent. The low air flow results in low gas velocity and minimal particulate entrainment. Combustion of the fuel rich gases is completed in the secondary chamber by the addition of air in excess of stoichiometric requirements. These units are commonly referred to as starved air modular systems. The second major subgroup of modular combustors operate with both combustion chambers in an excess air mode, and are referred to as excess air modular systems. The majority of modular systems contain refractory lined combustion chambers, and the more recently constructed units are equipped with waste heat boilers for energy recovery. More detailed design and operating information on all MWC design types is included in the MWC background information report for existing facilities and the MWC Report to Congress.[5,6]

3.0 POPULATION DESCRIPTION

This section characterizes the population of facilities that meet the definition of waste co-firing combustors by burning sewage sludge, medical waste, or wood waste, in a unit that is designed to burn MSW or RDF as a major fraction of total fuel input. Operating practices and available emissions data are summarized for each facility. Auxiliary fuel firing combustion practices are also discussed.

3.1 Sewage Sludge

Six plants that routinely burn sewage sludge with municipal solid waste have been identified in the existing MWC population. Table 3-1 presents design and operating information for each of the six facilities. The plants include units using conventional mass burn waterwall combustors, mass burn refractory wall combustors, modular excess air combustors, and FBCs. More complete plant descriptions are presented below.

3.1.1 Harrisburg, PA

The Harrisburg facility comprises two 360-tpd (327 tonnes/day) Martin mass burn waterwall MWCs equipped with two-field ESPs.[7] The plant began commercial operation in 1972, and both units operate continuously. Each boiler produces 92,500 lb/hr (41,957 kg/hr) of steam, the majority of which is sold to two customers. The remainder is used to generate electricity. A turbine generator was installed on site in November 1986. Sludge co-firing began in June 1975. The sewage sludge reportedly contains about 17 percent solids after being processed at the adjacent wastewater treatment plant. The plant fires about 50 tpd (45 tonnes/day) of sludge, which is delivered by truck and deposited into two hoppers on the tipping floor level. Below the hoppers are two 70-ton (63-tonne) holding tanks. The sludge is pumped from the holding tanks to mixing nozzles located at each charging hopper where it is blended with the MSW. The mixed waste is fed to the combustors by hydraulic rams. The units were recently upgraded (stokers and controls) and the current design approaches that offered in newer Martin MWCs. However, there is no air preheat. Oil is available as an auxiliary fuel for startup. It is not used during shutdown. The flue gases exit the boilers and enter separate ESPs at temperatures near 500°F (260°C).

TABLE 3-1. FACILITIES FIRING SEWAGE SLUDGE WITH MSW AND/OR RDF

Plant	Glen Cove, NY	Harrisburg, PA	New Canaan, CT	Sheboygan, WI	Sitka, AK	Duluth, MN
# of Units	2	2	1	2	2	2
Capacity (tpd)	125	360	125	120	25	120 RDF 345 sludge
Capacity (tonnes/day)	113	326	113	109	23	109 RDF/ 313 sludge
Combustion Type	Mass burn waterwall, waste heat boiler	Mass burn waterwall	Mass burn refractory wall	Mass burn refractory wall	Modular Excess Air	FBC
Manufacturer	Morse Boulger Zurn	Martin IBW	Detroit Stoker	Flynn & Emrich	Sigoure Freres York Shipley	Copeland Deltak
Sewage Sludge Mass Input Avg tpd/%	12.5 ea. 10%	25 ea 7%	<2%	<1%	8%	345 ea 74%
Comb. Start Date	1983	1972	1970	1964	1985	1980
Co-Firing Start Date	1983	1975	NA	NA	1985	1980
APCD	ESP	ESP	Venturi Scrubber	Wetted Baffles	Cyclone/ ESP	Venturi Scrubber
Ash Disposal	Combined off-site monofill	Combined on-site	Sanitary landfill	Off-site monofill	Combined off-site lined landfill	Municipal landfill cell
Sewage Sludge Injection Location	Charging hoppers	Charging hoppers	In pit	In pit	Charging hoppers	In bed

Harrisburg was the host site for a 1978 EPA research program to evaluate the impacts of sewage sludge/MSW co-incineration on corrosivity.[8] The study was conducted by Battelle for Industrial Environmental Research Laboratory (IERL) Cincinnati. The objective of the program was to determine the effect of low-chloride sewage sludge addition to MSW on the boiler tube metal wastage rates. The main conclusion of the study was that co-combustion of sewage sludge with MSW, combined with reduced sootblowing cycles, reduced metal wastage and extended the life of superheater tube materials. As a result of the program, it was recommended that co-firing should be encouraged as a means of reducing fire-side corrosion and, at the same time, providing sludge disposal. However, it was pointed out that any sewage burned should not be treated with ferric chloride because the chloride residue would promote corrosion. The beneficial effect of the sewage sludge was attributed to its silica content. It was also recommended that refuse-fired boilers be designed to keep gas temperatures in the superheater region as low as possible to reduce fire-side corrosion. APCD inlet emissions data were measured during the program while burning 100 percent refuse, and also while burning a mixture of refuse and 2-3 weight percent sewage sludge. These data are summarized in Table 3-2 and discussed in more detail in Section 4.

3.1.2 Glen Cove, NY

The Glen Cove co-disposal facility was designed to combust 225 tpd (204 tonnes/day) of MSW and 25 tpd (23 tonnes/day) of sewage sludge (20 percent solids) in two custom-designed refractory wall furnaces (individual unit capacities are 125 tpd [113 tonnes/day] each).[9] The plant operates 24 hours per day, seven days per week. Each furnace is equipped with a Morse Boulger reciprocating stoker and a separate Zurn waste heat boiler designed to produce 20,200 lb/hr (9,162 kg/hr) of steam. Steam is used to generate electricity for use in the wastewater treatment plant and the co-disposal facility. Flue gases from each boiler pass through separate two-field ESPs that normally operate near 560°F (293°C), and the flues converge into a single stack. The refractory-wall furnaces are custom designed with water tubes that line the furnace walls and serve a dual purpose of preheating the waste heat boiler feedwater and cooling the refractory in the combustion chamber. A profile of one unit is shown in Figure 3-1.[9]

Typical of conventional mass burn MWCs, MSW is delivered to a tipping area and dumped in a holding pit. Some bulky combustible waste is shredded

TABLE 3-2. APCD INLET EMISSIONS AT HARRISBURG INCINERATOR

(corrected to 7 percent 02)

	FLUE GAS COMPOSITION FOR FUEL INDICATED	
	REFUSE	REFUSE AND SEWAGE SLUDGE
SO2 (ppm)	170	290
HCl (ppm)	612	416
NOx (ppm)	134	101
CO (%)	.04	0

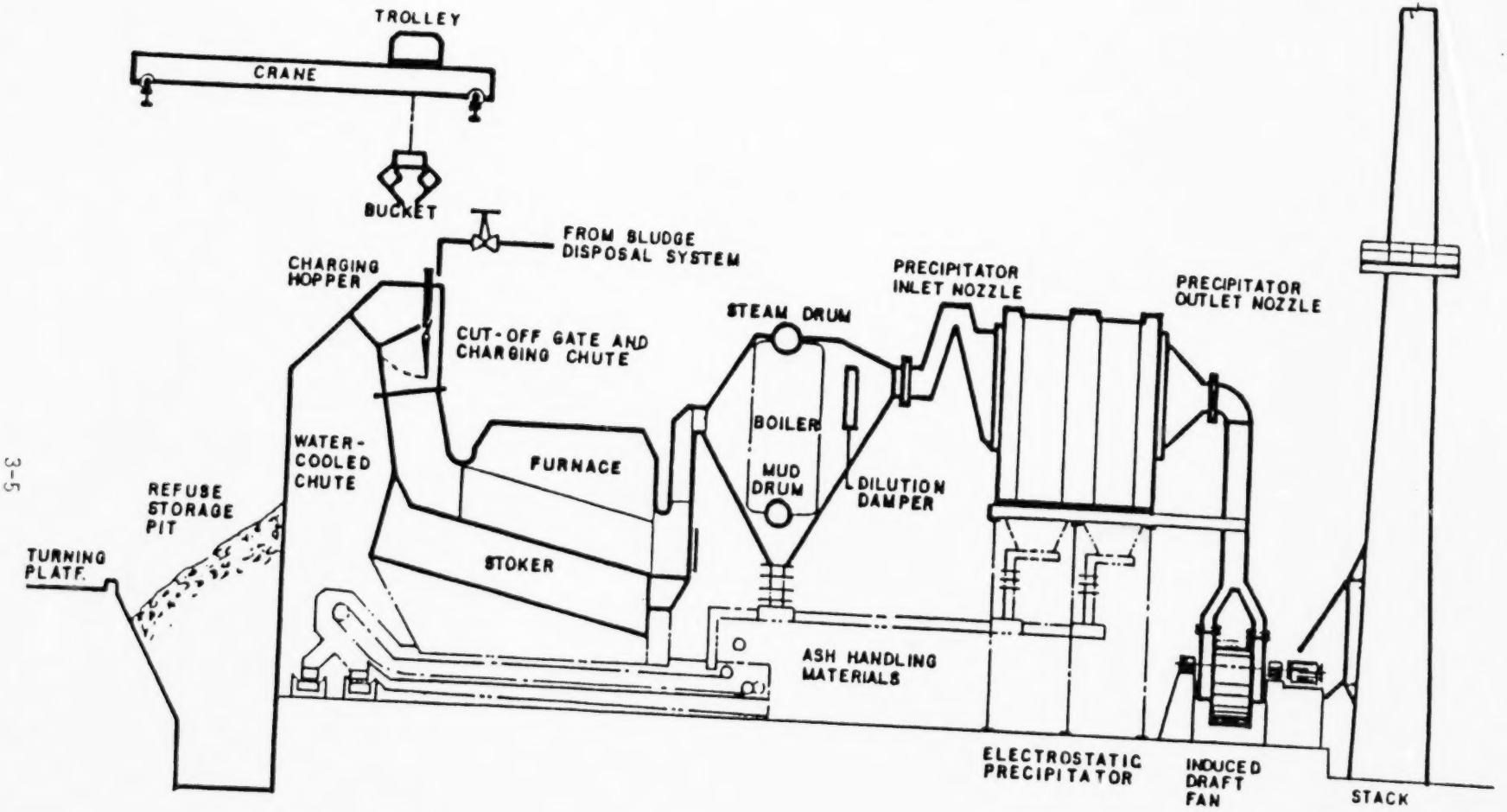

Figure 3-1. City of Glen Cove, New York
Sludge and Refuse Co-Disposal Complex

prior to being dumped in the pit. The sewage sludge is pumped from a wastewater treatment plant to the combustion facility where it is dewatered by centrifuges and conveyed to holding tanks. The sludge is then pumped out of the holding tank and into the charging hoppers where it is assimilated with the MSW. The MSW is charged by an overhead crane, and the waste mixture is fed by gravity to the furnaces. Each unit has two underfire air plenums and no air preheat. There is also no source of auxiliary fuel in the combustors. Gas temperatures are controlled by modulation of primary and secondary air flow rates. The grate speeds are adjusted to control waste burnout. Flue gases exit the combustor and pass through the waste heat boiler where the temperature is reduced to 500-600°F (260-315°C) prior to entering the ESPs. Fly ash and bottom ash are combined and co-disposed in an ash monofill in Ohio. The plant also has the ability to recover the ferrous component of the combined ash prior to disposal.

The permitted particulate matter (PM) and CO emission limits are reported to be 0.05 gr/dscf (corrected to 12 percent CO_2) and 1000 ppmv, respectively. Results from an emission test conducted in the Unit #1 stack in 1984 indicated a PM level of 0.042 gr/dscf (corrected to 12 percent CO_2) while charging 1000 lb/hr (45 kg/hr) sludge and 10,464 lb/hr (4746 kg/hr) MSW.[10] The unit operated with greater than 200 percent excess air (as measured in the stack). This is a typical operating value for a refractory wall combustor. The permit conditions were apparently met, based on the test results. CO emissions were measured by Orsat analysis and were reported to be 0.00 percent (1000 ppm = 0.10 percent).

3.1.3 New Canaan, CT

The New Canaan municipal incinerator is a 125-tpd (113 tonnes/day) unit with refractory wall construction and a Detroit Stoker reciprocating grate.[10] The unit reportedly operates 11 hours per day, five days per week and burns less than 2 percent sewage sludge by weight. The sludge is dumped by trucks and mixed in the MSW holding pit by the crane operator. The combustor is operated on a manual scheme. There is no air preheat and no auxiliary fuel available. Emission control is by a fixed throat venturi scrubber with a pressure drop of 10.5-11 inches (2615-2740 Pa) of water. Particulate stack testing has been conducted while burning 10 percent sludge (a higher percentage than reported for normal operation) and 90 percent MSW, and while

burning 100 percent MSW. The measured emissions were reported to be 0.151 gr/dscf and 0.18 gr/dscf, respectively (corrected to 7 percent O_2).

3.1.4 Sheboygan, WI

The Sheboygan incinerator began operating in 1964, using two refractory wall incinerators with individual firing capacities of 120 tpd (109 tonnes/day).[11] Each unit contains three Flynn and Emrich rocking grate sections. The plant operates 24 hours per day, 4-5 days per week. In addition to burning the city's MSW, sludge from the sewage treatment facility is also combusted. The sewage sludge comprises less than 1 percent of the facility's total waste input by weight. Emissions control is achieved by a wetted baffle chamber. The plant was one of the 12 sites visited in the MWC Retrofit Study. A detailed description of the facility's design and operation is included in the MWC background information report for existing facilities.[5]

3.1.5 Sitka, AK

The Sitka, AK facility comprises two 25-tpd (23 tonnes/day) Sigoure Freres modular excess air combustors with waste heat boilers and ESP controls.[12] The plant has been operating commercially since May 1985, and the normal operating schedule is 24 hours per day, five days per week. The plant reportedly burns 8 percent sludge, with 12.5 percent as a daily maximum. The sludge is 25-28 percent solids with a dry ash content of 27 percent. The dry heating value was measured and was reported to be 6287 Btu/lb (1.46×10^7 J/kg).[13] The sludge is delivered to the plant in roll-off containers and dumped into a live-bottom bin where screw transfer conveyors reduce it in size to one-inch diameter lumps and move it to a feed pump. The feed pump transfers the sludge through a 6 inch (0.15 m) diameter pipe to the combustor charging hopper where it is metered into the MSW feed. The waste is fed by a charging ram and is moved through the unit by a series of pneumatically-driven pokers. The combustor operates near 115 percent excess air and combustion takes place on stepped hearths in the primary combustion chamber, where the temperature reportedly averages 1700°F (927°C). The flue gas flows to a post-combustion chamber where average temperatures are reportedly near 1900°F (1038°C). There is no air injection in the secondary chamber; combustion air control is achieved by the induced draft (ID) fan. The flue gases flow from the combustor through the firetube boilers and ESPs, which are designed to operate at 450°F (232°C). The ESP plates are constructed of Corten steel to

reduce corrosion effects. Each ESP has one field. The units include oil burners which are used during startup and shutdown conditions. Permitted emission limits are 0.08 gr/dscf PM at 12 percent CO_2, and 20 percent opacity. Stack testing has been conducted on both units and PM emissions were reported to be 0.016 and 0.029 gr/dscf (corrected to 12 percent CO_2).[12] The ash is co-disposed in a lined landfill with leachate collection. No combustion problems have been reported as a result of firing the waste mixture.

3.1.6 Duluth, MN

The Western Lake Superior Sanitary District (WLSSD) located in Duluth, MN, combusts a mixture of sewage sludge and RDF in two Copeland Systems' FBCs. The units were primarily designed as sewage sludge incinerators that use RDF as an auxiliary fuel. A detailed description of facility design and operation, including measured emissions data, is presented in the "Municipal Waste Combustion Assessment, Fluidized Bed Combustion, July 1989, EPA/600-8-89-061" report.[3]

3.1.7 Projected New Population

The existing population of MSW/sewage sludge waste co-firing facilities includes the six plants described above. In addition, the Biddeford, ME RDF-fired facility has provisions in its operating permit to co-fire sewage sludge. Although sewage sludge handling equipment is on site, it has never been used, and plant personnel report that there are no future plans to co-fire sludge.[14]

There are at least nine facilities in planning, permitting, and construction phases that may burn a mixture of MSW and sewage sludge. A list of these facilities is included in Table 3-3.[15]

3.2 Medical Waste

There are at least 15 MWC facilities that have previously accepted or are currently accepting medical waste, including three mass burn waterwall, three mass burn refractory, three modular starved air, five modular excess air, and one fluidized bed combustor. Medical waste comprises from less than 1 percent to 50 percent by weight of waste burned at these facilities. The design and operating characteristics of these facilities are described in the

TABLE 3-3. PLANNED AND PROJECTED MWCs CO-FIRING SEWAGE SLUDGE

FACILITY	ANTICIPATED START DATE	SIZE (tpd)	SIZE (tonnes/day)	TECHNOLOGY	% SLUDGE
Huntsville, AL	1990	690	626	Mass burn waterwall	NA
San Bernardino, CA	NA	1.4 MW	NA	NA	
West Contra Costa County, CA	1989	435	394	Westinghouse, O'Connor	NA
Summit, IL	NA	1600	1451	NA	NA
Indianapolis, IN	1988	2000	1814	Mass burn waterwall	15
St. Louis, MO	1990	600	544	Mass burn waterwall	NA
Linden, NJ	NA	NA	NA	NA	20
Somerset, NJ	NA	720	653	NA	17
Lehigh Valley, PA (Allentown/Bethlehem)	1990	1000	907	Mass burn waterwall	NA

"Municipal Waste Combustion Assessment, Medical Waste Combustion Practices at MWC Facilities, July 1989, EPA-600/8-89-062" report.[16]

There are many new MWC projects planned for construction in the next few years. All of these facilities have the potential to accept medical waste along with MSW. Existing facilities also have the potential to begin accepting medical waste with their MSW. Ogden Martin Systems, Inc. has publicly announced that they plan to start co-firing medical waste in the Bristol, CT Resource Recovery Facility.[17] There are strong economic incentives for other MWCs to accept medical waste; much higher tipping fees can be charged for medical waste than for MSW. As a result of these incentives, there is a high potential for additional MWCs to accept medical waste on a routine basis.

3.3 Wood Waste

Wood waste is routinely fired in three MWC facilities located in Bay County, FL, Biddeford, ME, and Pigeon Point, DE. The design and operating characteristics of these facilities are summarized in Table 3-4.

3.3.1 Bay County, FL

The Bay County Resource Management Facility in Florida includes two 255-tpd (231 tonnes/day) mass burn rotary waterwall combustors.[18] Steam is produced at a rate of 70,000 lb/hr (31,751 kg/hr) per unit. MSW supplies are frequently inadequate to meet steam demands. Therefore, the facility frequently burns wood waste (bark or sawdust) in one combustor, and MSW or a mixture of MSW and wood waste in the other combustor. The estimated heating value of the mixture is 3800-4000 Btu/lb (8.84×10^6 - 9.30×10^6 J/kg), whereas the wood waste alone averages 3000-3500 Btu/lb (6.98×10^6 - 8.14×10^6 J/kg). On an annual average, wood waste supplies 30-40 percent of the total fuel mass. Waste feeding is accomplished by dual ram feeders. The feed rate is automatically controlled to maintain steam flows. The furnace exit temperature is 1200-1400°F (649-760°C). Underfire and overfire air supplies are both preheated. Oil burners are in place to supply auxiliary fuel at 40 percent of the design heat input. Auxiliary fuel is not used for startup or shutdown. Reportedly, steam is used to attain a preheat temperature of 300°F (149°C) measured at the furnace exit before waste feed is initiated. Bay County is equipped with a three-field ESP with a typical operating inlet gas

TABLE 3-4. FACILITIES FIRING WOOD WITH MSW AND/OR RDF

Plant	Bay County, FL	Biddeford, ME	Pigeon Point, DE
# of Units	2	2	5
Capacity (tpd)	255	350	120
Capacity (tonnes/day)	231	317	109
Combustion Type	Mass burn rotary waterwall	RDF	Modular excess air
Manufacturer	O'Connor/ Deltak	Detroit Stoker/ Babcock & Wilcox	Vicon
Wood Waste Mass Input Annual Average	30-40%	40%	10%
Combustor Start Date	1987	1988	1987
APCD	ESP (400)	Spray Dryer/ Fabric Filter	ESP (400)
Ash Disposal	MSW Landfill	Monofill	Monofill

temperature of 450°F (232°C). A more detailed description of the facility's design and operation is included in the MWC background information report for existing facilities.[5]

Table 3-5 summarizes emissions data from a recent compliance test at the Bay County facility.[19] Although Bay County routinely fires wood and MSW, the compliance test was conducted with 100 percent MSW. Therefore the effects of wood waste firing on emissions cannot be characterized.

3.3.2 Biddeford, ME

The MERC Waste-to-Energy Facility in Biddeford, ME comprises two 300-tpd (272 tonnes/day) spreader stokers which supply steam to a 21 MW_e turbine/generator.[20] Wood chips are routinely fired to supplement inadequate RDF supplies. The wood waste available to the facility is referred to as "green chips" by plant personnel, reflecting the high moisture content of the wood, reportedly 50 percent.[14] The boilers reportedly fire an annual average of 20 percent wood on a heat input basis (approximately 40 percent on a weight input basis). Natural gas is also available as auxiliary fuel and can carry 40 percent of the total furnace load. Natural gas is used during startup to achieve 1500-1800°F (815-982°C) in the furnace prior to waste feed. Auxiliary fuel is not used for shutdown. Underfire and overfire air are both preheated. Each unit is equipped with a spray dryer and fabric filter.

The Biddeford facility was tested for CDD/CDF by EPA in December 1987.[21] Emissions were measured at the spray dryer inlet in conjunction with compliance testing conducted in the stack. The unit that was tested was operating at full load during the test. Although an RDF/wood mixture is fired during normal operating conditions, 100 percent RDF was burned during the test. Therefore, the effects of wood waste firing on emissions cannot be characterized. Three CDD/CDF sampling runs were conducted at the APCD inlet and average emissions were 903 ng/dscm. Inlet PM emissions were 3.56 gr/dscf, and average CO emissions were 81 ppmv. The boiler was operated at approximately 65-70 percent excess air during the test with an overfire/underfire air ratio of 56/44. Each test run lasted four hours. The average temperature at the spray dryer inlet location was 374°F (190°C).

TABLE 3-5. BAY COUNTY, FLORIDA EMISSIONS SUMMARY

(Reference 19)

	UNIT 1	UNIT 2
Particulate Matter (dscfm)	0.0193	0.0243
SO2 (dry ppmv)	133	84
NOx (dry ppmv)	NA	169
HCl (dry ppmv)	428	508
CO (dry ppmv)	NA	68

All values corrected to 12 percent CO2 basis except CO, which is on 7 percent O2 basis.

3.3.3 Pigeon Point, DE

The Energy Generating Facility in Pigeon Point, DE, has five 120-tpd (109 tonnes/day) modular excess air combustors.[22] Two units converge to a single stack; the remaining three units have individual stacks. The primary fuel is an MSW/RDF mixture with a 1/5 mass ratio. Information concerning furnace temperature, air preheat, auxiliary fuel, startup and shutdown procedures, steam production, and/or electricity generation have been declared confidential by the facility. However, they do report firing about 10 weight percent wood annually. The facility is equipped with ESPs operating at an inlet gas temperature ranging from 393-493°F (200-256°C).

A compliance test at Pigeon Point was conducted in two phases.[23] Phase I consisted of HCl, SO_3, CO, and PM measurements made in the stack. Particulate testing was also conducted at the ESP inlet location for all four stacks. Phase II involved stack sampling for CDD/CDF and heavy metals (Pb, Hg, Be, Ni, As, Cd, Cr). Very limited process data are available for use in characterizing the operation of the Pigeon Point facility during testing, although it appears that a mixture containing only MSW and RDF was fired during the test. Therefore, the effects of wood waste firing on emissions cannot be characterized from these data.

The three-run average APCD inlet PM levels for each of the four flues tested were 1.03 gr/dscf, 1.03 gr/dscf, 0.90 gr/dscf, and 0.43 gr/dscf. One of the flues discharges gases from two combustors. Average flue gas temperatures entering the ESP ranged from 393-433°F (200-223°C). Three CDD/CDF sampling runs were conducted in the stack of Unit #2. The average emissions were reported to be 105 ng/dscm. The average stack temperature was reported to be 374°F (190°C). No continuous CO monitoring data are available. The CO data included in this test report were measured by ORSAT analysis and were reported to be 0.0 percent by volume (1000 ppmv = 0.1 percent).

3.3.4 Projected New Population

There are at least 13 facilities in planning, permitting, and construction phases that may burn a mixture of wood and MSW. A list of these facilities is included in Table 3-6.[15]

TABLE 3-6. PLANNED AND PROJECTED MWCs CO-FIRING WOOD

FACILITY	ANTICIPATED START DATE	SIZE (tpd)	SIZE (tonnes/day)	TECHNOLOGY	% WOOD
Petersburg, AK	NA	NA	NA	NA	NA
Lake County, FL	NA	500	454	NA	NA
Collier County, FL	NA	600-900	544-816	Gotaverken CFB	NA
Coeur d'Alene, ID	NA	9.7 MW		FBC	40
Penobscot, ME	1988	25 MW		RDF Spreader Stoker	NA
SE Baltimore, MD	1990	1200	1088	FBC	NA
Conway, NH	NA	150	136	NA	NA
Keene, NH	NA	300	272	Rotary Waterwall	NA
Portsmouth, NH	NA	800	726	NA	NA
Linden, NJ	NA	19 MW		NA	15
Ocean City, NJ	NA	1500	1360	Mass Burn Waterwall	NA
Beaver County, PA	NA	12 MW		NA	NA
Lyndonville, VT	NA	200	181	FBC	60

3.4 Auxiliary Fuel Fired MWCs

Auxiliary fuel firing, as defined in Section 2.1, is limited to those MWCs that produce steam, and is generally practiced only as necessary to maintain steam load when waste supplies are curtailed or interrupted. Although there may be some mass burn facilities that fire auxiliary fuel when waste is not available, auxiliary fuel firing is more commonly practiced by RDF spreader stokers than by other design types. Because of the manner in which feeding takes place (air swept distributors), plugging of feed mechanisms is a more persistent problem in RDF spreader stokers. Therefore, it is necessary to have the ability to fire an auxiliary fuel in order to maintain steam load when these problems occur. Table 3-7 provides a list of the existing RDF spreader stoker MWCs and identifies their auxiliary fuel types and capacities.[24] A brief description of each of these facilities is provided below.

3.4.1 Columbus, OH

The City of Columbus operates six spreader stoker boilers, each with a rated capacity of 500 tpd (454 tonnes/day) of RDF, producing steam and generating electricity.[25] The facility began firing RDF in August, 1983, and the original operating philosophy was to burn a mixture of 20 percent coal and 80 percent RDF by heat input.[26] Serious operating problems related to fuel processing, fuel feeding, erosion/corrosion, slagging, and ash handling combined to cause frequent outages and high maintenance costs. A major modification program was initiated at the facility in February 1985 and completed two years later. One major operational change involved a decision to burn RDF or coal separately in the boilers, but not simultaneously. Current operating conditions include either four or five boilers operating simultaneously at 80-100 percent load on 100 percent RDF, with coal available as a supplemental or emergency fuel. The City has experimented with 5-10 percent of total fuel input being supplied by shredded tires with positive results, but there are no plans in the future to co-fire coal with RDF. The boilers are equipped with cyclones and four-field ESPs that reportedly operate near 600°F (316°C). No auxiliary fuels other than coal are fired in the boilers.

Particulate and NO_x emissions data are available from Columbus while firing 100 percent coal, and a 20 percent coal/80 percent RDF mixture.[25]

TABLE 3-7. EXISTING RDF SPREADER STOKERS - AUXILIARY FUEL CAPACITIES

PLANT LOCATION	MANUFACTURER STOKER/BOILER	# OF UNITS	UNIT SI (tpd)	UNIT SI (tonnes/day)	YEAR OF STARTUP	APCD	AUXILIARY FUEL	% RATED CAPACITY
Albany, NY	Zurn Zurn	2	300	272	1981	ESP	Gas	100
Niagara Falls, NY	Detroit Stoker Foster Wheeler	2	1000	907	1981	ESP	Gas	100
Dade County, FL	Detroit Stoker Fives Cail Babcock (1)	4	750	680	1982	ESP	Gas	100
Akron, OH	Detroit Stoker B&W	2	300	272	1979	ESP	Gas	100
Columbus, OH	Detroit Stoker B&W	6	400	363	1983	Cyclone/ESP	Coal	100
Lawrence, MA	Detroit Stoker B&W	1	1000	907	1984	ESP	NA	NA
Red Wing, MN	Detroit Stoker Foster Wheeler (2)	2	360	326	1987	ESP	Gas	100
Mankato, MN	Detroit Stoker B&W (2)	2	360	326	1987	ESP	Gas	100
Portsmouth, VA	CE CE	4	480	435	1988	ESP	Oil Coal	30 100
Biddeford, ME	Detroit Stoker B&W	2	350	317	1988	Spray dryer/ Fabric filter	Gas	40
Orrington, ME	Detroit Stoker B&W	2	360	326	1988	Spray dryer/ Fabric filter	NA	NA
Hartford, CT	CE CE	3	667	605	1988	Spray dryer/ Fabric filter	Coal Gas	100 14

1. Undergoing modifications by Zurn - auxiliary fuel is included in modification.
2. Modified by B&W.

Total particulate concentrations measured in the stack varied from 0.007 gr/dscf (corrected to 7 percent O_2) with 100 percent coal to 0.014 gr/dscf with the mixed waste. NO_x emissions when burning 100 percent coal were nearly twice as high as NO_x emissions while burning 20 percent coal/80 percent RDF, due to the higher fuel nitrogen content of coal.

3.4.2 Hartford, CT

The Mid-Connecticut RDF facility in Hartford processes 2000 tpd (1814 tonnes/day) of MSW and burns RDF in three spreader stoker boilers.[24] The firing rate at maximum continuous rating is approximately 675 tpd (612 tonnes/day) RDF (or 232 tpd [210 tonnes/day] coal) per boiler. The facility is currently going through acceptance testing and is expected to be operating commercially in the next few months. Although each boiler has the potential to simultaneously fire RDF and coal, the current operating philosophy will be to burn 100 percent RDF whenever possible. Compliance testing has been conducted in the stack under two separate conditions--while firing 100 percent RDF and firing a coal/RDF mixture. CDD/CDF emissions were measured downstream of the control device (spray dryer/fabric filter). The 1988-1989 parametric testing program at Mid-Connecticut will provide a detailed performance evaluation of the units.

3.4.3 Portsmouth, VA

The U.S. Navy owns and operates four spreader stoker boilers, each designed to burn 480 tpd (435 tonnes/day) of RDF, at the Norfolk Naval Shipyard in Portsmouth, VA.[27] The facility began operating in 1987, and each unit is designed to burn a mixture of RDF and coal. However, the boilers will reportedly be operated on 100 percent RDF whenever possible. Each boiler is also equipped with oil burners capable of providing 30 percent of design heat input which are used for startup. Emission controls for each unit are a cyclone and a four-field ESP. The typical ESP inlet gas temperature is 490°F (254°C).

3.4.4 Additional RDF/Coal Fired MWCs

At least one additional RDF-fired facility (Occidental Chemical Corporation, Niagara Falls, NY which comprises two 1100-tpd [998 tonnes/day] units) was designed to burn RDF and/or coal. However, the units have not burned coal

for several years, and there are no plans to resume this practice.[5] Two additional facilities have been identified that plan to co-fire RDF and coal in FBC boilers. The plants are located in Reno, NV and Tacoma, WA. Both facilities will include two 500-tpd (454 tonnes/day) FBCs.[15] There are currently no CDD/CDF data available from RDF spreader stokers co-firing coal. Testing at Mid-Connecticut in 1988-89 should provide these data.

3.4.5 Albany, NY

Emissions testing was conducted at the Albany, NY facility in 1984 while firing 100 percent RDF and also while firing RDF with 15 percent natural gas.[28] CDD/CDF emissions were measured in the stack during both tests. The tetra- through hepta-CDD/CDF homologue groups were quantified (no octa-CDD/CDF) for both test conditions. Total CDD/CDF emissions were 440 ng/dscm while firing 100 percent RDF, and 840 ng/dscm while firing 85 percent RDF with 15 percent natural gas. The natural gas burners are located on the rear wall of the boiler at an elevation approximately half way between the traveling grate and the overfire air ports. It is suspected that, when the gas burners are operating, mixing patterns may be disrupted in the boiler, increasing vertical gas velocities in the lower portion of the combustion chamber. This may allow pockets of unburned material (gaseous and solid) to escape the boiler without being properly mixed, resulting in higher CDD/CDF emissions in the stack.

Based on these limited data, it appears that an important design criterion for auxiliary fuel fired systems is the location of auxiliary fuel injection. The best way to establish the optimum location is through flow modeling studies.

4.0 GOOD COMBUSTION PRACTICES

The existing population of waste co-fired MWCs includes all combustor design types, and each of these combustor types can potentially burn a wide variety of waste and fossil fuel mixtures. The currently available emissions data base does not support any conclusion that, for a given combustor design, CDD/CDF emissions from waste co-firing facilities will differ substantially from 100 percent MSW or RDF combustion. CDD/CDF emissions have been measured from many combustion sources, including units that burn sewage sludge, wood, coal, and medical waste.[29,30,31,32] However, for these fuels, CDD/CDF emission levels appear to be more dependent on combustion conditions than they are on waste feed characteristics. Based on this information, it can be assumed that all of the waste co-firing MWCs can be adequately represented by one of the 111(b) or 111(d) model plants, and that additional model plant development specifically for waste co-firing MWCs is not necessary.[24,33]

The good combustion practices that have been developed for MSW and RDF combustors are based on two main concepts:

1) Sufficient mixing must be achieved at adequate temperature to maximize the destruction of trace organics.
2) Conditions that promote low temperature formation of trace organics must be minimized.

These basic concepts apply to all MWC systems, and hence, to all waste co-firing MWCs. They are necessary conditions for minimization of CDD/CDF emissions.

Table 4-1 presents the components of MWC good combustion practice.[34] The requirements that will minimize CDD/CDF emissions do not change based on waste feed. However, when firing a mixture of wastes and/or fossil fuels, conditions may arise that will impose limitations on operation. For example, the high moisture content of sewage sludge may impose a maximum sludge firing rate to maintain the required temperature at the fully mixed location. A typical sewage sludge with 20 percent solids and a dry heating value of 7000 Btu/lb (1.63×10^7 J/kg) will have a net as-fired heat input near zero. Therefore, the heat required to maintain temperatures in the combustor must be contributed from an additional source. It may be necessary for mass burn systems to have air preheat or to fire an auxiliary fuel when burning

TABLE 4-1. COMPONENTS OF GOOD COMBUSTION PRACTICE

COMPONENT	OBJECTIVE
Waste feed control	• Avoid combustion instabilities
Combustion temperature	• Ensure destruction of gas-phase organics
Amount and distribution of combustion air	• Eliminate fuel-rich zones and quenching
	• Provide proper local stoichiometries in waste drying, ignition, combustion, and burnout zones
	• Minimize PM entrainment
	• Provide local fuel-rich zone to minimize NOx formation
Mixing	• Ensure availability of oxidant to all organic material within high temperature region of the combustor
PM carryover	• Minimize furnace emission of organics and PM
Downstream temperature control	• Minimize downstream formation of organics

MSW/sludge mixtures. These considerations are important when designing new systems or retrofitting existing MWCs to fire sludge along with MSW. In some cases, excess air levels and combustion air distributions will also change slightly when co-firing waste. However, the majority of design, operation/control, and verification elements do not change for a given combustor when it fires a mixture of MSW or RDF and sewage sludge.

Combustion of wood waste, particularly in RDF spreader stokers, may contribute to high carryover of entrained particulate matter. This condition may contribute to low-temperature downstream formation mechanisms that lead to higher CDD/CDF emissions. As a result, it is important to design all systems to minimize the potential for these conditions to occur. The current recommended combustion practices address this concern.

Auxiliary fuel firing in MWCs should be designed so that adequate mixing at necessary temperatures occurs for all firing conditions. This can be accomplished by conducting flow modeling studies on new and existing boilers to determine the optimum location and firing rate for auxiliary fuel burners that will be used in combination with MSW or RDF combustion. By applying appropriate design and operating practices to ensure good mixing, auxiliary fuel firing MWCs can maintain low emissions of air pollutants in accordance with the current good combustion practices.

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